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Correlation Between Relative Handgrip Strength Index as well as Chronotropic Response Index and Heart Rate Recovery Index

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ABSTRACT

Introduction: This study evaluated the relationship between relative handgrip strenght index (rHGSi) as well as chronotropic response index (Cri) and heart rate recovery index (HRRi), which are the prognostic parameters of treadmill exercise.

Patients and Methods: In total, 490 patients who were recommended to undergo the exercise electrocardiographic test were recruited in this study. The participants were divided into two groups based on both Cri (normal and low CRi groups) and rHGSi (high and low rHGSi groups).

Results: The treadmill exercise time, peak heart rate, and metabolic equivalents were higher in the high rHGSi group than in the low rHGSi group. In addition, the 1st minute HRRi and Cri were higher in the high rHGSi group than in the low rHGSi group. The treadmill exercise time, basal and peak heart rate, metabolic equivalents, and 1st minute HRRi were significantly lower in the low CRi group than in the normal Cri group. rHGSi was considered an independent predictor of low chronotropic response index. Based on a bivariate analysis, a statistically significant positive correlation was observed between Cri and rHGSi. Similarly, there was a positive association between rHGSi and 1st minute HRRi.

Conclusion: rHGSi might be a practical and effective tool in cardiovascular risk stratification.

Key Words: Relative handgrip strength; heart rate recovery; low chronotropic index

Rölatif El Kavrama Gücü İndeksi ile Kronotropik Cevap İndeksi ve Kalp Hızı Toparlanma İndeksi İlişkili mi?

ÖZET

Giriş: Bu çalışmada, rölatif el kavrama gücü indeksi ile egzersiz testinin önemli prognostik belirteçleri olan kronotropik cevap indeksi ve kalp hızı toparlanma indeksi arasındaki ilişki araştırılmıştır.

Hastalar ve Yöntem: Treadmill egzersiz testi planlanan 490 hasta çalışmaya alındı. Çalışma grubu el kavrama gücü indeksi ve kronotropik cevap indeksi değerlerine göre ayrı ayrı ikişer gruba ayrıldı.

Bulgular: Yüksek rölatif el kavrama gücü indeksi grubunda, treadmill egzersiz zamanı, zirve kalp hızı ve metabolik ekivalan değeri düşük rölatif el kavrama gücü indeksi gruba kıyasla daha yüksek bulunmuştur. Ek olarak kronotropik cevap indeksi ve birinci dakika kalp hızı toparlanma indeksi gibi prognostik parametreler de yüksek rölatif el kavrama gücü indeksi grubunda daha yüksek bulunmuştur. Çalışma grubunu kronotropik cevap indeksine göre gruplandırıp incelediğimizde, treadmill egzersiz zamanı, bazal ve zirve kalp hızı, metabolik ekivalan ve birinci dakika ve kalp hızı toparlanma indeksi değerleri düşük kronotropik cevap indeksi grubunda yüksek kronotropik cevap indeksi gruba kıyasla daha düşük tespit edilmiştir. Ek olarak, rölatif el kavrama gücü indeksi düşük kronotropik cevap indeksinin bağımsız öngörücüsü olarak saptanmıştır. Yapılan çalışmada kronotropik cevap indeksi ve rölatif el kavrama gücü indeksi arasında pozitif korelasyon saptanmıştır. Aynı şekilde birinci dakika kalp hızı toparlanma indeksi ve rölatif el kavrama gücü indeksi arasında da istatistiksel olarak anlamlı derecede korelasyon saptanmıştır.

Sonuç: Rölatif el kavrama gücü indeksi popülasyonda kardiyovasküler risk sınıflandırması için kullanışlı ve pratik bir araçtır.

Anahtar Kelimeler: Rölatif el kavrama gücü indeksi; kalp hızı toparlanma indeksi; kronotropik cevap indeksi

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INTRODUCTION

Handgrip strength has been considered a reliable, effective, and cost-effective method that can be used to easily assess skeletal muscle function in the general population. When handgrip strength is measured while in sitting position, it can reveal the forearm and upper limb muscle strength. However, the lower limb and core muscle strengths are identified when measured while in standing position[1]. According to recent studies, handgrip strength is a powerful variable that can provide useful information regarding increased risk of mortality[2]. Relative handgrip strength index (rHGSi) is defined as the sum of the handgrip strength of both hands divided by body mass index (BMI), and it is considered a better prognostic tool than handgrip strength[3]. Similarly, Kawamoto et al. showed the relationship between lower cardiometabolic risk and higher handgrip strength, which are calculated using the weight adjusted formula[4]. An attenuated heart rate response to exercise has been considered a predictive factor for the risk of mortality and coronary heart disease[5]. Chronotropic response index (CRi) is defined as the index of heart rate reserve used[6,7]. An impaired chronotropic response reflects, in part, an underlying abnormality in autonomic nervous system function[8,9]. Furthermore, CRi can be used to predict the increased or decreased risks of ischemia and mortality based on the exercise electrocardiogram test for heart rate reserve[6,7]. Heart rate recovery index (HRRi) is another significant prognostic factor associated with cardiovascular mortality and morbidity based on the exercise electrocardiogram test[10]. Under normal physiologic conditions, the heart rate declines within the first few minutes of exercise. A decrease in this parameter within the first 30 s to 1 min after exercise is primarily correlated with parasympathetic reactivation[11]. The current study aimed to evaluate the association between rHGSi as well as CRi and HRRi in patients who underwent the treadmill exercise test.

PATIENTS and METHODS

In total, 490 consecutive patients who were recommended to undergo the exercise electrocardiogram test in our hospital were recruited in this study. All patients underwent the test in our hospital according to the Modified Bruce protocol. The exclusion criteria included a history of coronary artery disease, congestive heart failure, valvular heart disease, pre-excitation syndrome, or congenital heart disease. Moreover, patients taking beta-blockers, those with contraindications to the exercise test, and those with abnormalities on baseline ECG that can obscure electrocardiographic changes during exercise were not included in the study. Handgrip strength was determined using a handgrip hydraulic dynamometer. Three measurements on the right and left hands were obtained, and the highest value was recorded. The patients were in standing position while the forearm was in neutral position and the elbow was fully extended while the measurement was performed. Moreover, all participants received verbal encouragement withing 1-min rest intervals between measurements. To calculate the rHGSi, the highest reading from each hand was divided by the participant's body mass index (BMI), which was calculated as height (to the nearest 0.1 cm) divided by body weight (to the nearest 0.1 kg) (body weight/height^2). Hypertension and diabetes were diagnosed according to the current guidelines[12,13]. Patients underwent the treadmill exercise test using the modified Bruce protocol. Moreover, they were encouraged to exercise until voluntary exhaustion and 85% of the maximum predicted heart rate is achieved. During each exercise and recovery stage, symptoms (chest discomfort, rate of perceived exertion, and dizziness), blood pressure, and heart rate were monitored. After the peak exercise (maximum time spent in the test), the participants walked for a 2-minute cool-down period at 2.0 km/h. HRRi was defined as a reduction in heart rate from the rate during the peak exercise to the rate within 1 and 2 min after discontinuing the exercise stress testing. An HRRi ≤ 12 beats/min is not normal. For safety purposes, the participants were allowed to lean on handrails during exercise[14]. CRi was calculated using the formula [(peak HR-resting HR)/(220-age in years-resting HR). Abnormal response was defined as a CRi < 0.8[14]. The study population was divided into two groups based on CRi. The cutoff value for CRi was 0.80, and the patients with a CRi > 0.80 were included in the normal group. The rest of the participants with a CRi < 0.80 were included in the low CRi group. In addition, the study population was divided into two groups (low and high rHGSi groups). The cutoff points for grouping the patients based on the rHGSi in this study were 2.5 for men and 1.5 for women[3]. This study was approved by the ethics committee of Bahcesehir University and was conducted according to the principles of the Declaration of Helsinki. A written informed consent was obtained from all study participants.

Statistical Analysis

Visual (histograms, probability plots) and analytical methods (the Kolmogorov-Smirnov/Shapiro-Wilk test) were used to determine whether the variables were normally distributed. Continuous variables with a parametric distribution were expressed as mean ± standard deviation and those with non-parametric distribution as median and interquartile range. Parametric continuous variables were analyzed using the student's t-test, and the non-parametric continuous variables using the Mann-Whitney U test. Categorical data were expressed as frequencies, and their differences were analyzed using the chi-square test. The CRi and rHGSi had a normal distribution, and the correlation coefficients and their significance were calculated using the Pearson test. A multiple logistic regression model was used to identify the independent predictors of chronotropic response index. Age, female sex, hypertension, metabolic equivalents (METs), and relative handgrip strength were included in the univariate logistic regression analysis. Then, variables with a p value < 0.05 were included in the multivariate logistic regression analysis. A statistical analysis was performed using the Statistical Package for the Social Sciences software version 23.0 (SPSS Inc., Chicago, Illinois, the USA). A $p < 0.05$ was considered statistically significant.

RESULTS

In total, 490 patients were enrolled in this study. The participants were divided into two groups according to CRi (normal and low CRi groups). In addition, the participants were divided into two groups based on the relative handgrip strength index (rHGSi) (high or low rHGSi groups). The baseline clinical characteristics of the patients in the high and low rHGSi groups are presented in Table 1. The rHGSi were 2.9 ± 0.6 in the high rHGSi group and 1.7 ± 0.5 in the low rHGSi group. The proportion of patients who were older (56.7 ± 9.7 vs. 47.9 ± 11.4; p< 0.001), women (42.5% vs. 17.4%, p< 0.001), and obese with a high prevalence of hypertension (50.7% vs. 33.1%; p< 0.001) and diabetes mellitus (31.5% vs. 19.2%, p= 0.003) was higher in the low rHGSi group than in the high rHGSi group. In terms of the relationship between the exercise treadmill test parameters and rHGSi, the treadmill exercise time, peak heart rate, and metabolic equivalents (MET) were significantly higher in the high rHGSi group than in the low rHGSi group. In addition, 1st min HRRi (26.9 ± 11.4 vs. 18.7 ± 10.1; p< 0.001) and CRi (0.96 ± 0.16 vs. 0.79 ± 0.19; p< 0.001) were higher in the high rHGSi group than in the low rHGSi group, as shown in Table 1.

The demographic and baseline data of the study population that was divided into two groups as low CRi and normal groups were depicted on the Table 2. The patients in the low CRi group were more likely to be obese, women, and older. The prevalence of hypertension was higher in the low CRi group than in the high CRi group. The rHGSi was significantly lower in the low rHGSi group than in the high rHGSi group (2.1 ± 0.8 vs. 2.7 ± 0.8; p< 0.001). During the exercise treadmill test, the treadmill exercise time basal and peak heart rate, MET, and 1st min HRRi were significantly lower in the low CRi group than in the high CRi group, as shown Table 2. Based on the univariate analysis, age, female sex, MET, and rHGSi were found to be correlated with Cri (Table 3). Moreover, the multivariate logistic regression analysis revealed that rHGSi was an independent predictor of low CRi (odds ratio: 0.263; 95% confidence interval: 0.164-0.421; p< 0.001) after adjusting for age, female sex, hypertension, and MET (Table 3).

Table 1. Demographic, baseline, and clinical characteristics of all participants and the exercise test variables of the high and low relative handgrip strength index groups

Variables	High rHGSi group (n= 344)	Low rHGSi group (n= 146)	p
Age (years)	47.9 ± 11.4	56.7 ± 9.7	< 0.001
Gender (female, %)	60 (17.4)	62 (42.5)	< 0.001
Height (m)	172.8 ± 7.8	165.3 ± 9.3	< 0.001
Body weight (kg)	81.6 ± 14	82.3 ± 14	0.588
Body mass index (kg/m^2)	27.2 ± 3.9	29.9 ± 3.9	< 0.001
Hypertension (%)	114 (33.1)	74 (50.7)	< 0.001
Diabetes mellitus (%)	66 (19.2)	46 (31.5)	0.003
Cigarette (%)	138 (40.1)	40 (27.4)	0.007
Relative handgrip strength index	2.9 ± 0.6	1.7 ± 0.5	< 0.001
Treadmill exercise time (min.)	9.3 ± 1.6	7.2 ± 2.1	< 0.001
Basal heart rate (bpm)	83.2 ± 13.1	80.2 ± 16.7	0.056
Peak heart rate (bpm)	168.2 ± 16.5	146.3 ± 16.6	< 0.001
1st minute heart rate recovery index (bpm)	26.9 ± 11.4	18.7 ± 10.1	< 0.001
2nd minute heart rate recovery index (bpm)	48.6 ± 11.7	37.4 ± 14.9	< 0001
Metabolic equivalents	12.5 (11-13.3)	9.2 (7.2-11.5)	< 0.001
Chronotropic response index	0.96 ± 0.16	0.79 ± 0.19	< 0.001

Table 2. Demographic, baseline, and clinical characteristics of all participants and the exercise test variable of the normal and low chronotropic response index groups

Variables	Normal CRi group (n= 358)	Low CRi group (n= 132)	p
Age (years)	49.5 ± 11.5	53.6 ± 10.4	0.001
Gender (female, %)	76 (21.2)	46 (34.8)	0.002
Height (m)	171 ± 9.1	169.5 ± 8.6	0.117
Body weight (kg)	81.2 ± 14	83.4 ± 14	0.121
Body mass index (kg/m^2)	27.6 ± 4	29 ± 4.2	0.001
Hypertension (%)	128 (35.8)	60 (45.5)	0.05
Diabetes mellitus (%)	76 (21.2)	36 (27.3)	0.158
Cigarette (%)	126 (35.2)	52 (39.4)	0.391
Relative handgrip strength index	2.7 ± 0.7	2.1 ± 0.8	< 0.001
Treadmill exercise time (min.)	9.2 ± 1.6	7.5 ± 2.4	< 0.001
Basal heart rate (bpm)	83.3 ± 13.9	79.6 ± 15.5	0.013
Peak heart rate (bpm)	169 ± 15.3	141.8 ± 14.4	< 0.001
1st minute heart rate recovery index (bpm)	25.7 ± 11.2	21.03 ± 11.9	< 0.001
2nd minute heart rate recovery index (bpm)	47.7 ± 13.3	38.5 ± 12.6	< 0.001
Metabolic equivalents	12.2 (10.2-13.3)	10 (8.1-12.8)	< 0.001

Table 3. The results of low chronotropic response index of univariate and multivariate analysis results

	Univariate analysis		Multivariate analysis	
Variable	OR (95% CI)*	p	OR (95% CI)*	p
Age	1.032 (1.013-1.052)	0.001	1.009 (0.988-1.031)	0.419
Gender (female)	1.985 (1.280-3.077)	0.002	0.527 (0.274-1.016)	0.056
Hypertension	1.497 (0.999-2.245)	0.051	-	-
Metabolic equivalents	0.919 (0.846-0.998)	0.046	1.035 (0.998-1.073)	0.066
Relative handgrip strength index	0.367 (0.273-0.493)	< 0.001	0.263 (0.164-0.421)	< 0.001

* Odds ratio confidence interval.

The correlation bivariate analysis revealed a statistically significant positive association between CRi and rHGSi ($r= 0.289$; $p< 0.001$). Furthermore, a positive correlation was found between 1st min HRRi and rHGSi ($r= 0.252$; $p< 0.001$) (Figures 1, 2).

DISCUSSION

This study evaluated the relationship between rHGSi as well as CRi and HRRi, which are the prognostic parameters of treadmill exercise test. A positive correlation was found between rHGSi as well as CRi and HRRi. Moreover, a low rHGSi was found to be a predictive parameter of low CRi.

The prognostic relevance of handgrip strength has been confirmed in general and clinical populations. Previous studies have already confirmed that a higher handgrip strength is associated with a lower mortality. Moreover, Lee WJ et al. showed that in adults aged 53 years and older in the normal population, a lower rHGSi was associated with cardiometabolic risk factors such as blood pressure and triglyceride, total cholesterol, high-density cholesterol, fasting blood glucose, and glycated hemoglobin levels[3]. The PURE study revealed an inverse association between grip strength and all-cause mortality, cardiovascular and non-cardiovascular mortality, myocardial infarction, and stroke during a 4-year follow-up[15]. The association

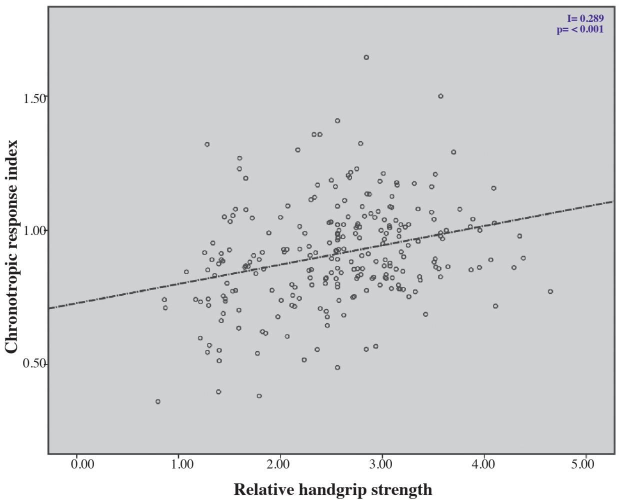

Figure 1. Correlation curve of the relative handgrip strength and chronotropic response index.

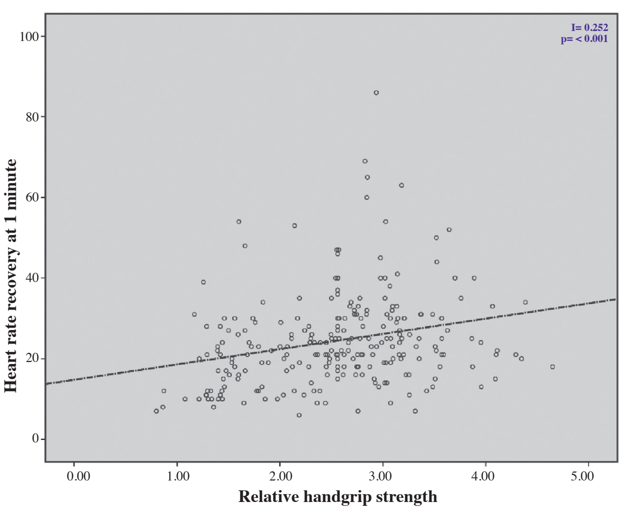

Figure 2. Correlation curve of the relative handgrip strength and heart rate recovery at 1 minute.

between handgrip strength and mortality was observed among not only elderly individuals but also young- and middle-aged individuals[16].

Compared with absolute handgrip strength, rHGSi, which is referred to as the dominant handgrip strength, adjusted for BMI was significantly associated with more favorable cardiovascular health biomarkers[3]. In the current study, this parameter was used to evaluate muscle strength. Other than ST segment depression, CRi and HRRi are also considered as significant prognostic parameters.

Chronotropic incompetence is an inability of the heart rate to increase normally with exercise. Studies on population-based and clinical cohorts have shown that an impaired chronotropic response is a predictive factor of cardiac events and all-cause mortality[5,17]. A major challenge in using chronotropic response in clinical exercise testing is determining how best to characterize it. CRi is a significant parameter that reflects heart rate reserve and calculated peak exercise heart rate adjusted for age. A low heart rate reserve is defined as a CRi < 0.80. Some studies have shown that CRi is a better predictor of mortality than age-predicted heart rate[18].

HRRi is another parameter that reflects heart rate reserve on the treadmill test. A 1st min HRRi value ≤ 12 bpm was considered the best value for predicting mortality and morbidity[7]. HRRi can predict death independent of confounders, including left ventricular systolic function, functional capacity, and angiographic severity of coronary disease[10]. Myers et al. compared CRi and HRRi in terms of predicting cardiovascular mortality[19]. Both parameters were found to be predictors of cardiovascular mortality in patients who were recommended to undergo exercise testing for clinical reasons. Moreover, CRi was a better tool than HRRi in predicting cardiovascular mortality[19]. Some studies showed a relationship between handgrip strength and chronotropic incompetence. A previous study has revealed that a lower rHGSi is associated with autonomic damage and lower heart rate variability in patients with diabetes[20]. A study on older obese women assessed the relationship between handgrip rHGSi as well as CRi and HRRi. Results showed that individuals with a higher rHGSi had a higher CRi and HR recovery[21]. In the current study, patients of both gender and those aged over 18 years were included. Similar to previous studies, CRi and HRRi were found to be positively correlated with rHGSi. Both CRi and HRRi were lower in the patients with reduced rHGSi. Treadmill exercise duration and MET were also higher in the high rHGSi group than in the low rHGSi group. In addition, after assessing CRi and other prognostic confounders, results showed that old age, female sex, and MET were associated with a low CRi. However, based on the multivariate analysis, only low rHGSi was considered an independent predictor of low CRi. The current study had a limitation. That is, only a small number of participants were included.

In conclusion, compared with individuals with a high rHGSi, those with a low rHGSi had lower CRi and HRRi based on the exercise treadmill test. Furthermore, a low rHGSi was an independent predictor of low CRi. Thus, rHGSi might be a practical and effective tool in cardiovascular risk stratification.

Ethics Committee Approval: Ethics committee approval was received for this study from the Bahcesehir University Clinical Researchs Ethics Committee (No: 2020-05/04, Date: 18/03/2020).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

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